Interlabial gap and freeway space at rest position: a cephalometric study

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Objectives: The aim of this prospective study was to assess the amount of interlabial gap (ILG) and freeway space (FWS) at rest position (RP) according to gender, age, and skeletal pattern, and to evaluate the cephalometric measurements at maximum intercuspal position (MIP) and at RP to define the cephalometric changes from MIP to RP related to the amount of ILG and FWS.
Methods: Lateral cephalograms and photographs of selected subjects (47 females, 57 males) were obtained at MIP and RP. Cephalometric measurements at MIP and RP and their differences were measured and compared.
Results: ILG ($P > 0.05$) and FWS ($P < 0.01$) were greater in males than in females. ILG ($P < 0.05$) and FWS ($P > 0.05$) were greater in adolescents than in adults. ILG and FWS were not significantly related with the vertical skeletal pattern (FHR, facial height ratio). ILG was the greatest in Class II cases but without significance. FWS was significantly greater in Class III than in Class I and Class II cases ($P < 0.05$). At MIP, the ILG at RP increased as overjet ($P < 0.05$) and upper lip to the aesthetic line ($P < 0.01$) increased. At RP, the ILG increased as upper incisor exposure and the lips to the aesthetic line increased ($P < 0.001$), and FWS decreased as overbite decreased ($P < 0.001$). From MIP to RP, lip length showed the greatest decrease ($P < 0.001$) in the large ILG group. Additionally, Bjork sum (the sum of the saddle, articular, and gonial angles), mandibular plane angle, anterior facial height, and ANB ($P < 0.001$) showed the greatest increase, while OB ($P < 0.001$) showed the greatest decrease in the large FWS group. The lip competent group showed the largest frequency distribution in the small ILG and FWS groups, while smile line frequency distribution showed no relationship with the level of ILG and FWS.
Conclusions: Taking cephalometric measurements at RP would be helpful to evaluate the ILG and FWS more accurately, and to provide a more accurate diagnosis and treatment plan.
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Introduction

Maximum intercuspal position (MIP) has been defined as the complete intercuspation of opposing teeth independent of condylar position.[1] Physiologic rest position (RP) has been defined as the assumed mandibular position when the head is in an upright position and the involved muscles are at equilibrium in tonic contraction.[1] This position has provided a mandibular reference for analysis and reconstruction of the occlusion.[2] At RP, the teeth are slightly apart and the perioral soft tissue and mandibular posture are both unstrained.[3]

Zachrisson[4] demonstrated that the single most important diagnostic record for treatment might be facial photographs of the lips at RP because it will help compare the amount of maxillary incisor display when the patient is functioning. Yogosawa[5] suggested that a pre-treatment relaxed lip posture offered a framework for the prediction of post-treatment facial profile change. Burstone[6,7] considered that the most functional and reproducible position was a relaxed lip position which may be used as a guide for tooth positioning. Zachrisson[4] and Dindaroglu et al.[8] also achieved high reproducibility of rest position by instructing the patient to say “Emma”.

The interlabial gap (ILG)[6,9,10] is the space between the relaxed upper and lower lips. It represents the shortest linear dimension between the inferior surface of the upper lip and the superior surface of the lower lip. Burstone reported that the average ILG at RP was 3.7 mm in adolescents.[6] Bergman et al.[9] further suggested that the average ILG at RP was 4.0 and 3.0 mm in females and males at age 6, respectively, and 2.0 mm at age 18 years. Ghorbanyjavadpour and Rakhshanet[10] demonstrated that an appropriate ILG was essential for good profile aesthetics.

Freeway space (FWS) or inter-occlusal distance is the difference in the vertical dimension at RP and MIP. Several authors[2,11–17] have reported variable average FWS values from 1.0 to 10.0 mm depending on facial type, malocclusion, and measurement methods. Impinging upon normal FWS can result in undue stimulus to the stretch reflex of the masticatory muscles, leading to excessive muscle contractions which may affect the functional occlusion.[14] Therefore, orthodontists need to evaluate FWS in each patient and establish a treatment plan for appropriate vertical control.

Previous studies have assessed the soft tissue profile to emphasise the importance of proper ILG and FWS.[10,14] However, to the best of current knowledge, there have been few comprehensive reports on ILG and FWS evaluated by lateral cephalograms at RP. Therefore, the present study aimed to assess the amount of interlabial gap (ILG) and freeway space (FWS) according to gender, age, and skeletal pattern, using cephalometric measurements at MIP and RP to determine changes from MIP to RP relative to the amount of ILG and FWS. The null hypothesis would state that there is no difference between groups related to gender, age, skeletal patterns, or the initial amount of ILG and FWS at MIP and RP.

Material and methods

Sample selection

Using G*Power (version 3.1.9.2; Franz Faul, Christian-Albrechts-Universitat, Kiel, Germany) an analysis was performed to determine sample size parameters. Using a two-tail design, the effect size of 0.36 and a total sample size of 102 produced an estimated α error probability of 0.05, β error probability of 0.10 and power of 0.90.

The sample inclusion criteria identified patients who visited the clinic and were systemically healthy, and the exclusion criteria were those presenting with (1) a facial midline deviation of more than 2 mm,[18] (2) a history of orthodontic treatment, (3) an airway problem, (4) difficulty complying with instructions, and (5) a history of orthognathic or plastic surgery.

One hundred and forty-six consecutive patients who met the inclusion criteria were identified. Of those, the exclusion criteria removed 42 patients. Samples were therefore obtained from 104 patients (47 females, 57 males; mean age, 16.4 ± 9.8 years) who had visited the orthodontic clinic in the Wonkwang University Daejeon Dental Hospital in Daejeon, Korea, from May 2019 to February 2020 (Table I). The lateral cephalograms and photographs of the included subjects were obtained at MIP and RP (Figure 1A–D). The patients or parents provided consent and agreed to one additional lateral cephalogram at RP to assist in diagnosis.

Institutional review board approval was granted by Wonkwang University Daejeon Dental Hospital (number WKD IRB W2005/001/001) in Daejeon, Korea, to conduct the study.

Data collection and classification

The subjects were informed verbally and visually about MIP and RP. Each patient was instructed to achieve MIP by keeping their teeth gently in occlusion. RP was generated by asking the patients to say “Emma” and then relax their lips for 1–2 sec.[4,8] To confirm the reproducibility of RP, the superimposition of a radiograph on a photograph was performed (Figure 1E, F). The groups were divided according to gender, age, ILG, FWS, facial height ratio (FHR) and ANB angle. Small, medium, and large groups were divided according to the level of the ILG and FWS, respectively (Table I).

Table I. Sample distribution (*n*).

Variables	Sex		Gender			ILG			FWS			FHR			ANB		
			Child	Adolescent	Adult	Small	Medium	Large	Small	Medium	Large	Hyper	Normo	Hypo	Class III	Class I	Class II
	M	F	y<12	12≤y≤18	y>18	ILG<3 mm	3 mm≤ILG ≤4 mm	ILG>4 mm	FWS <1.2 mm	1.2 mm≤FWS ≤2 mm	FWS>2 mm	FHR<62%	62%≤FHR ≤65%	FHR>65%	ANB<1°	1°≤ANB ≤4°	ANB>4°
Sex																	
Male	47		17	18	12	14	16	17	13	12	22	6	14	27	11	21	15
Female		57	23	17	17	26	15	16	23	19	15	19	18	20	8	27	22
Age																	
Child	17	23				12	16	12	14	8	18	11	14	15	7	21	12
Adolescent	18	17				10	11	14	10	11	14	8	10	17	7	10	18
Adult	12	17				18	4	7	12	12	5	6	8	15	5	17	7
ILG																	
Small	14	26	12	10	18				19	12	9	11	10	19	10	18	12
Medium	16	15	16	11	4				7	11	13	6	10	15	5	17	9
Large	17	16	12	14	7				10	8	15	8	12	13	4	13	16
FWS																	
Small	13	23	14	10	12	19	7	10				10	9	17	4	20	12
Medium	12	19	8	11	12	12	11	8				7	12	12	4	13	14
Large	22	15	18	14	5	9	13	15				8	11	18	11	15	11
FHR																	
Hyper	6	19	11	8	6	11	6	8	10	7	8				2	12	11
Normo	14	18	14	10	8	10	10	12	9	12	11				7	14	11
Hypo	27	20	15	17	15	19	15	13	17	12	18				10	22	15
ANB																	
Class III	11	8	7	7	5	10	5	4	4	4	11	2	7	10			
Class I	21	27	21	10	17	18	17	13	20	13	15	12	14	22			
Class II	15	22	12	18	7	12	9	16	12	14	11	11	11	15			
Total (each)	104		40	35	29	40	31	33	36	31	37	25	32	47	19	48	37

ILG, interlabial gap; FWS, freeway space; FHR (facial height ratio, %), posterior facial height (S-Go)/anterior facial height (N-Me); hyper, hyperdivergent; normo, normovergent; hypo, hypodivergent.

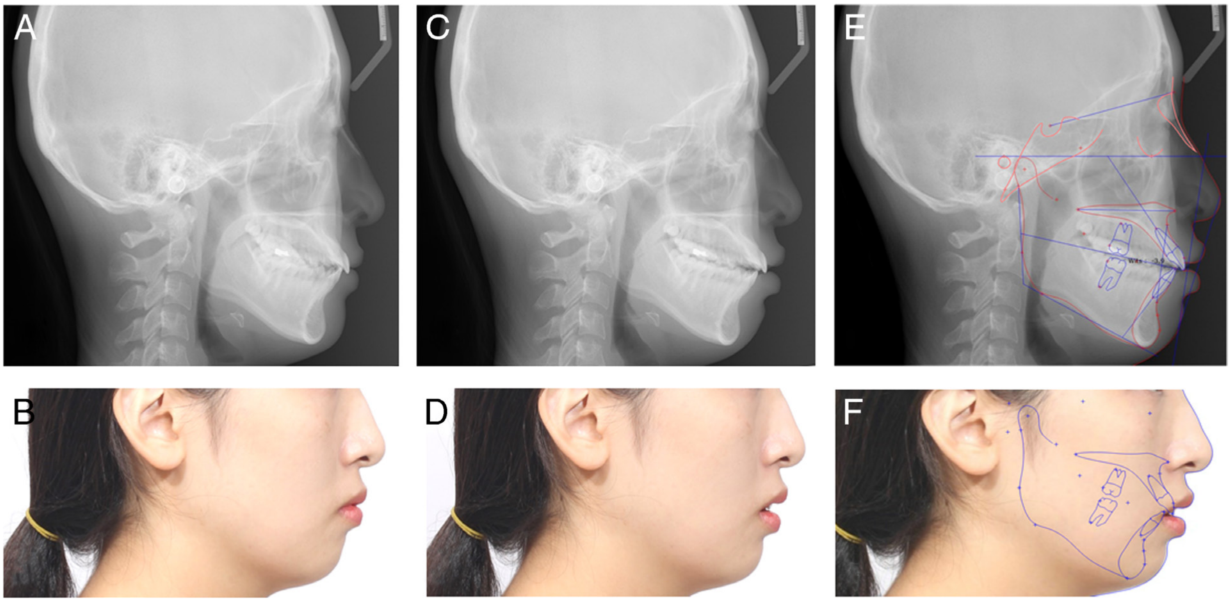

Figure 1. Lateral cephalograms and profile photographs at maximum intercuspal position (MIP) (A and B) and rest position (C and D). Tracing on the lateral cephalogram and profile photograph at rest (E and F).

Cephalometric measurements

The definitions and abbreviations of the cephalometric variables applied in this study are listed in Table II. Lateral cephalograms at MIP and RP were traced, and anatomical landmarks and planes were identified (Figure 2A), and linear and angular measurements were conducted (Figure 2B, C). Upper incisor exposure (UIE), ILG, and FWS were additionally measured at RP (Figure 2D). The measurements were made by one examiner (Y.J.S.) using the V-Ceph program (version 8.0; Osstem Implant, Seoul, Korea).

Statistical analysis

The intraclass correlation (ICC) was found to range between 0.927 and 0.999, ensuring intra-observer reliability. An independent sample *t*-test and an analysis of variance were performed to determine the difference of ILS and FWS according to gender, age, FHR, and the ANB angle. An analysis of variance was performed to determine the differences of the cephalometric variables according to the amount of ILG and FWS at MIP and RP, and to reveal the cephalometric changes between MIP and RP according to the level of ILG and FWS. A non-parametric chi-square test was performed to identify the distribution of lip competence and incompetence, plus smile line distribution according to the amount of ILG and FWS.

Results

The ILG was greater in males than in females but without significance, while FWS was significantly greater in males than in females ($P < 0.01$). The ILG ($P < 0.05$) and FWS ($P > 0.05$) were greater in adolescents than in adults. The ILG was smaller and FWS was greater in hypodivergent patients than in hyperdivergent and normovergent patients. The ILG was the greatest in Class II subjects without significance while FWS was significantly greater in Class III than Class I and in Class II subjects ($P < 0.05$) (Table III).

At MIP, the ILG at RP increased as overjet ($P < 0.05$) and upper lip to the aesthetic line ($P < 0.01$) increased (Table IV). At RP, the ILG increased as upper incisor exposure and the lips to the aesthetic line increased ($P < 0.001$), and FWS decreased as overbite decreased ($P < 0.001$) (Table V).

From MIP to RP, lip length showed the greatest decrease ($P < 0.001$) in the large ILG group. Additionally, Bjork sum (the sum of the saddle, articular, and gonial angles), the mandibular plane angle, anterior facial height, and ANB angle showed the greatest increase ($P < 0.001$), while OB showed the greatest decrease ($P < 0.001$) in the large FWS group (Table VI). The lip competent group showed the greatest frequency distribution in the small ILG and FWS groups. The frequency distribution of the

Table II. Definitions of the cephalometric variables used in this study.

Variables	Definition
Distances (mm)	
AFH (anterior facial height)	Distance between nasion to menton
PFH (posterior facial height)	Distance between sella to gonion
AO-BO (Wits appraisal)	Distance between point A and point B parallel to occlusal plane
OJ (incisor overjet)	Distance between the incisal tips of the mandibular and maxillary central incisors parallel to the occlusal plane
OB (incisor overbite)	Distance between the incisal tips of the mandibular and maxillary central incisors perpendicular to the occlusal plane
UADAH (upper anterior dentoalveolar height)	Perpendicular distance between the incisal tips of the maxillary central incisors and palatal plane
UPDAH (upper posterior dentoalveolar height)	Perpendicular distance between the mesiobuccal cusp tips of the maxillary first molars and palatal plane
LADAH (lower anterior dentoalveolar height)	Perpendicular distance between the incisal tips of the mandibular central incisors and palatal plane
LPDAH (lower posterior dentoalveolar height)	Perpendicular distance between the mesiobuccal cusp tips of the mandibular first molars and palatal plane
UL-EL (upper lip-esthetic line)	Perpendicular distance between the upper lip anterior and esthetic line connecting the pronasale and soft tissue pogonion
LL- EL (lower lip-esthetic line)	Perpendicular distance between the lower lip anterior and esthetic line connecting the pronasale and soft tissue pogonion
ULL (upper lip length)	Distance between subnasale to stomion superioris perpendicular to the Frankfort horizontal (FH) plane connecting porion and orbitale
LLL (lower lip length)	Distance between soft tissue menton to stomion inferioris perpendicular to the Frankfort horizontal (FH) plane
ULT (upper lip thickness)	Distance between the most labial point of the maxillary central incisors and upper lip anterior
LLT (lower lip thickness)	Distance between the most labial point of the mandibular central incisors and lower lip anterior
MLSD (mentolabial sulcus depth)	Perpendicular distance between soft tissue point B and line connecting the lower lip inferior and soft tissue pogonion
STCT (soft tissue chin thickness)	Distance between pogonion and soft tissue pogonion
FWS (freeway space)	Perpendicular distance between the mesiobuccal cusps of the maxillary first molars and the mandibular posterior occlusal plane connecting the mesiobuccal cusps of the mandibular first and second molars
ILG (interlabial gap)	Distance between the upper and lower stomions perpendicular to the SN-7 (7° to the sella-nasion line through the sella)
UIE (upper incisor exposure)	Distance between the upper stomion and incisal edge of the maxillary incisor at rest position
Angles (°)	
Bjork Sum	Sum of SA (saddle angle), AA (articular angle), and GA (gonial angle)
MPA (mandibular plane angle)	Angle between FH plane and mandibular plane connecting menton and gonion
PPA (palatal plane angle)	Angle between FH plane and palatal plane connecting the anterior nasal spine and posterior nasal spine
ANB	Angle formed by point A, nasion, and point B

U1 to FH	Angle between the long axis of the maxillary incisors and FH plane
IMPA (incisor-mandibular plane angle)	Angle between the mandibular plane and long axis of the mandibular central incisors
IIA (interincisal angle)	Angle between the long axes of the maxillary and mandibular central incisors
OPA (occlusal plane angle)	Angle between FH plane and occlusal plane connecting the midpoint of the mesiobuccal cusp tips of the maxillary and mandibular first molars and midpoint of the incisal tips of the maxillary and mandibular central incisors
NLA (nasolabial angle)	Angle formed by columella, subnasale, and labiale superius
MLA (mentolabial angle)	Angle formed by lower lip anterior, soft tissue point B, and soft tissue pogonion
Z-angle	Angle between FH plane and line tangent to soft tissue pogonion and vermillion border of the most prominent lips

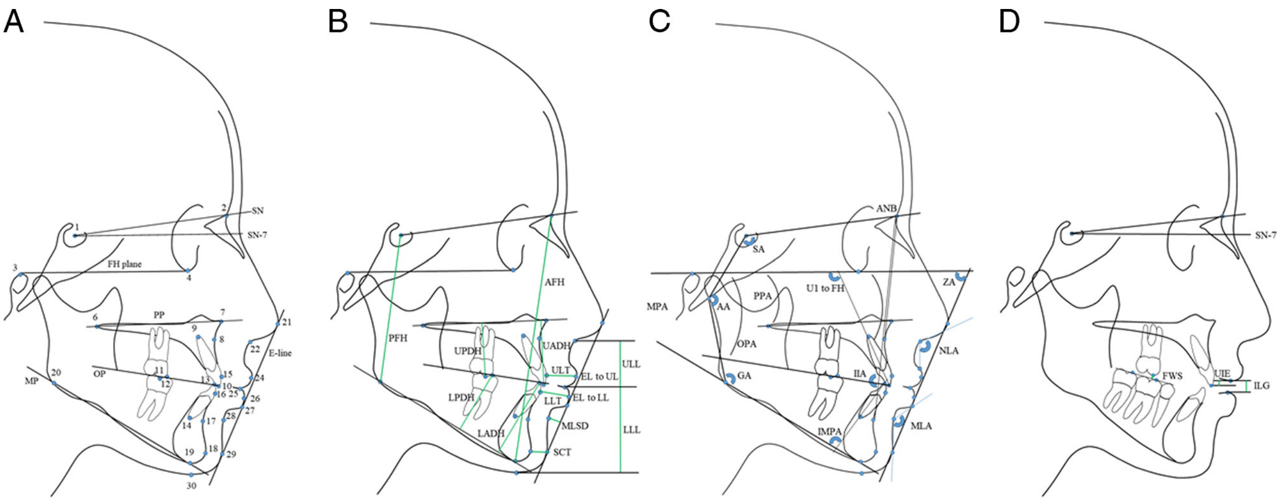

Figure 2. Cephalometric landmarks and measurements. A. Anatomical landmarks and planes on a lateral cephalogram: 1, sella; 2, nasion; 3, porion; 4, orbitale; 5, articulare; 6, posterior nasal spine; 7, anterior nasal spine; 8, point A; 9, root tip of the maxillary incisor (U1); 10, tip of U1; 11, mesiobuccal cusp of the maxillary first molar (U6); 12, mesiobuccal cusp of the mandibular first molar (L6); 13, tip of the mandibular incisor (L1); 14, root tip of L1; 15, most labial point of U1; 16, most labial point of L1; 17, point B; 18, pogonion; 19, menton; 20, gonion; 21, pronasale; 22, subnasale; 23, upper lip superior; 24, upper lip anterior; 25, stomion; 26, lower lip anterior; 27, lower lip inferior; 28, soft tissue point B; 29, soft tissue pogonion; 30, soft tissue menton; SN-7, 7° to the sella-nasion line through the sella; FH plane, Frankfort horizontal plane; PP, palatal plane; OP, occlusal plane; MP, mandibular plane; E-line, esthetic line. B. Cephalometric linear measurements: AFH, anterior facial height; PFH, posterior facial height; UADAH, upper anterior dentoalveolar height; UPDAH, upper anterior dentoalveolar height; LADAH, lower anterior dentoalveolar height; LPDAH, lower posterior dentoalveolar height; EL to UL, esthetic line to upper lip; EL to LL, esthetic line to lower lip; ULL, upper lip length; LLL, lower lip length; ULT, upper lip thickness; LLT, lower lip thickness; MLSD, mentolabial sulcus depth; STCT, soft tissue chin thickness. C. Cephalometric angular measurements: ANB; SA, saddle angle; AA, articular angle; GA, gonial angle; MPA, mandibular plane angle; PPA, palatal plane angle; ANB angle; U1 to FH; IMPA, mandibular incisor-mandibular plane angle; IIA, interincisal angle; OPA, occlusal plane angle; NLA, nasolabial angle; MLA, mentolabial angle; ZA, Z angle. D. Cephalometric additional measurements at rest position: ILG, interlabial gap; UIE, upper incisor exposure; FWS, freeway space.

smile line showed no relationship with the amount of ILG and FWS (Table VII).

Discussion

The vertical dimension (VD) at RP was determined using facial measurements of soft-tissue landmarks,[19] but several authors[20,21] have concluded that facial measurements using skin markers are inappropriate for determining FWS because the vertical movement of the mandible is not always equal to the movement of the facial soft tissues. Therefore, the present study used lateral cephalograms at MIP and RP to more accurately measure ILG and FWS, and, in addition, the reproducibility of RP in each patient was confirmed by superimposing a profile photograph over a lateral cephalogram (Figure 1).

In the present study, the amount of ILG and FWS was greater in males than in females and the average ILG and FWS were 3.6 and 1.9 mm, respectively. This supported the results of previous studies.[6,9,16,17] A longitudinal study[9] of cephalometric soft tissue

Table III. Interlabial gap (ILG) and freeway space (FWS) according to gender, age, and skeletal patterns (mm).

	Means (standard deviations) and *P* values															
	Total (*n*=104)	Male (*n*=47)	Female (*n*=57)	*P* value	Child (*n*=40)	Adolescent (*n*=35)	Adult (*n*=29)	*P* value	Hyper (*n*=25)	Normo (*n*=32)	Hypo (*n*=47)	*P* value	Class III (*n*=19)	Class I (*n*=48)	Class II (*n*=37)	*P* value
ILG	3.56 (1.74)	3.84 (1.89)	3.34 (1.58)	0.152	$3.52^{a,b}$ (1.54)	4.08^{b} (2.02)	3.01^{a} (1.47)	0.045* (.058)	3.55 (2.13)	3.65 (1.41)	3.52 (1.75)	.946 (.517)	3.29 (1.67)	3.47 (1.71)	3.83 (1.82)	.473 (.374)
FWS	1.87 (1.24)	2.25 (1.46)	1.56 (0.92)	0.006**	1.89 (1.14)	2.06 (1.40)	1.62 (1.15)	0.371 (0.323)	1.61 (0.84)	1.88 (1.16)	2.01 (1.45)	0.433 (0.768)	2.63^{b} (1.73)	1.78^{a} (1.21)	1.61^{a} (0.76)	0.010* (0.080)

Hyper, hyperdivergent; Normo, normovergent; Hypo, hypodivergent. The Shapiro-Wilk normality test was performed and the nonparametric test results are presented in parentheses when normality was not satisfied.
The letter a<b indicated differently was analysed by Scheffe's homogeneous subset group ($P < 0.05$), and there was a significant difference between the means. *$P < 0.05$; **$P < 0.01$.

profile traits in patients between the ages of 6 and 18 years suggested that the ILG decreases with age. Peter et al.[22] also found that the ILG decreased from childhood to adolescence. However, in the present study, the ILG increased from childhood to adolescence without significance but significantly decreased from adolescence to adulthood. The possible reason why these results varied from previous studies[9,22] might be because the current study was cross-sectional in nature and the age ranges were different. Therefore, a longitudinal study with a greater sample size might be necessary to overcome this limitation.

Iwahashi et al.[23] suggested that an increased OJ affected lip competence, which could be improved by decreasing the OJ. This finding was similar to the present results in which the ILG increased as OJ increased and the lip incompetent group was proportionally greater in the large ILG group. Leonardo et al.[24] indicated that a long AFH was observed in the group with lip incompetence. In the present study, AFH was greatest in the large ILG group which related to lip incompetence. Hassan et al.[25] found that the lip incompetent group had a smaller interincisal angle (IIA) along with a greater dentoalveolar height (DAH) and ANB angle, and U1 to FH, which reflected the present results. Lip competence was more prevalent in the small and medium ILG and small FWS than in the other groups. This might be explained by a more advantageous position and structure of the lips in those groups when the patients had an ability to comfortably seal their lips.

Lindegard[26] found that FWS was negatively correlated with AFH but showed a positive correlation with PFH. Peterson et al.[27] and Michelotti et al.[17] concluded that the low MPA group had a greater opening of FWS at RP. Wessberg et al.[28] found that FWS showed a negative correlation with vertical dentofacial morphology at RP. In addition, in the present study, FWS was greater in hypodivergent patients than in hyperdivergent and normovergent patients.

Sakar et al.[29] found that the differences in the closest speaking space which is similar to FWS were not significant between horizontal skeletal patterns, while in the present study, FWS was significantly greater in Class III patients than in Class I and Class II patients. Furthermore, the ILG was the greatest in Class II

Table IV. Cephalometric measurements at maximum intercuspal position (MIP) according to the amount of interlabial gap (ILG) and freeway space (FWS) at rest position (RP).

	Means (SD, mm) and *P* values								
	Total (*n*=104)	ILG<3 (*n*=40)	3≤ILG≤4 (*n*=31)	ILG>4 (*n*=33)	*P* value	FWS<1.2 (*n*=36)	1.2≤FWS≤2 (*n*=31)	FWS>2 (*n*=37)	*P* value
Skeletal variables									
Sum	395.74 (6.14)	395.73 (6.12)	394.45 (5.75)	396.95 (6.43)	0.268	397.11 (6.64)	395.23 (5.17)	394.82 (6.29)	0.245
MPA	27.39 (5.37)	27.58 (5.05)	25.86 (4.39)	28.59 (6.32)	0.122	28.54 (6.24)	26.83 (4.41)	26.74 (5.15)	0.287
PPA	1.08 (3.22)	1.48 (2.88)	0.95 (2.51)	0.70 (4.13)	0.570 (0.578)	1.27 (3.64)	1.17 (3.00)	0.81 (3.04)	0.815
AFH	129.09 (10.62)	130.02^{a,b} (11.75)	125.12^{a} (8.81)	131.67^{b} (9.93)	0.035* (0.057)	130.35 (11.54)	129.85 (10.70)	127.21 (9.58)	0.405
PFH	84.09 (9.56)	84.61 (9.86)	82.44 (9.88)	85.02 (8.95)	0.514	83.64 (8.09)	85.52 (10.56)	83.33 (10.11)	0.609 (0.771)
FHR (PFH/AFH)	65.12 (4.74)	65.09 (4.90)	65.75 (4.67)	64.57 (4.67)	0.615	64.31 (4.86)	65.74 (4.40)	65.40 (4.91)	0.428 (0.599)
ANB	3.02 (2.77)	2.32 (3.03)	2.98 (2.25)	3.91 (2.73)	0.051	3.28 (2.55)	3.45 (2.36)	2.41 (3.23)	0.239
AO-BO	−2.75 (4.07)	−3.50 (5.05)	−3.02 (3.07)	−1.59 (3.36)	0.122 (0.064)	−2.77 (3.42)	−1.86 (3.83)	−3.48 (4.76)	0.263 (0.471)
Dental variables									
OJ	3.57 (3.06)	2.59 (3.35)	3.81 (2.70)	4.53 (2.71)	0.021$ (0.014$)	3.57 (2.74)	4.22 (2.48)	3.02 (3.69)	0.276 (0.380)
OB	2.11 (1.98)	1.59 (2.03)	2.57 (2.00)	2.30 (1.79)	0.093	1.90 (1.92)	2.19 (1.78)	2.24 (2.21)	0.738
U1 to FH	114.57 (7.85)	114.81 (6.35)	112.65 (9.90)	116.09 (7.16)	0.211	114.93^{a,b} (6.59)	117.30^{b} (7.93)	111.95^{a} (8.26)	0.017* (0.051)
IMPA	94.46 (7.95)	93.13 (8.97)	93.41 (7.97)	97.05 (5.98)	0.074 (0.040)	95.26 (7.83)	96.02 (7.89)	92.38 (7.90)	0.129
IIA	123.58 (11.05)	124.48^{a,b} (8.99)	128.07^{b} (12.63)	118.27^{a} (9.76)	0.001**	121.28^{a} (9.86)	119.86^{a} (9.57)	128.93^{b} (11.48)	0.001**
OPA	12.30 (4.31)	11.66 (3.66)	12.53 (4.33)	12.87 (4.99)	0.466	12.74 (3.84)	11.48 (4.89)	12.57 (4.24)	0.447
UADH	30.94 (3.28)	30.71^{a,b} (3.46)	29.78^{a} (2.94)	32.29^{b} (2.95)	0.007**	31.44 (3.39)	31.02 (3.47)	30.37 (3.00)	0.378
UPDH	24.15 (3.86)	24.69 (4.09)	22.73 (3.59)	24.83 (3.56)	0.048$ (0.056)	24.53 (3.87)	24.64 (4.11)	23.37 (3.60)	0.309
LADH	44.16 (4.53)	43.87^{a,b} (4.60)	42.70^{a} (3.72)	45.90^{b} (4.69)	0.015*	44.38 (4.67)	44.84 (4.53)	43.39 (4.40)	0.398
LPDH	34.82 (3.98)	34.52 (4.23)	34.11 (3.54)	35.87 (3.94)	0.172 (0.167)	34.74 (3.46)	35.52 (4.60)	34.33 (3.90)	0.469 (0.450)
Soft tissue variables									
NLA	95.33 (10.98)	93.73 (11.61)	94.29 (11.01)	98.26 (9.87)	0.177	97.72 (9.12)	94.66 (12.65)	93.58 (11.04)	0.254
UL-EL	1.30 (3.20)	−0.08^{a} (3.14)	1.63^{a,b} (2.58)	2.65^{b} (3.21)	0.001** (<0.001***)	1.41 (3.51)	1.38 (2.74)	1.12 (3.32)	0.913 (0.951)
LL-EL	2.71 (3.15)	2.13^{a} (3.13)	2.06^{a} (2.53)	4.02^{b} (3.37)	0.013* (0.010*)	3.22 (3.37)	2.74 (2.71)	2.19 (3.26)	0.381 (0.496)
ULL	28.03 (3.32)	27.99^{a,b} (3.39)	26.65^{a} (3.05)	29.37^{b} (3.02)	−.004**	28.70 (3.26)	28.10 (3.55)	27.32 (3.11)	0.208
LLL	48.56 (5.26)	48.84 (5.76)	46.95 (4.74)	49.74 (4.84)	0.096	48.29 (5.33)	48.48 (4.80)	48.89 (5.67)	0.884
LLR (LLL/ULL)	2.03 (0.23)	2.02 (0.26)	2.03 (0.21)	2.04 (0.21)	0.958 (0.797)	1.97 (0.22)	2.03 (0.21)	2.08 (0.24)	0.107 (0.120)
MLA	148.53 (12.30)	149.88 (11.90)	144.95 (12.17)	150.26 (12.57)	0.153	147.71 (11.63)	149.55 (12.25)	148.47 (13.22)	0.832

MLSD	3.71 (1.45)	3.57 (1.40)	4.11 (1.65)	3.50 (1.28)	0.182	3.75 (1.35)	3.57 (1.39)	3.78 (1.62)	0.814
ULT	14.27 (2.58)	14.11 (2.13)	14.89 (2.89)	13.90 (2.75)	0.272	13.44^{a} (2.32)	13.72^{b} (1.98)	15.55^{c} (2.81)	0.001**
LLT	15.90 (2.17)	15.70 (2.17)	16.03 (2.06)	16.02 (2.33)	0.766	15.59 (2.06)	15.58 (1.89)	16.47 (2.43)	0.141
STCT	14.14 (5.03)	13.57 (2.12)	15.41 (8.24)	13.64 (3.16)	0.248 (0.624)	13.28 (2.00)	14.95 (8.21)	14.30 (3.30)	0.391 (0.509)
Z-angle	73.87 (5.64)	74.27 (5.83)	75.01 (5.24)	72.29 (5.60)	0.132(0.110)	73.11 (5.00)	73.51 (5.87)	74.90 (6.02)	0.367

FHR, facial height ratio, PFH/AFH (%); LLR, lip length ratio, LLR/ULR (%). The Shapiro–Wilk normality test was performed and the nonparametric test results are presented in parentheses when normality was not satisfied. The letter a < b indicated differently was analysed by Scheffe's homogeneous subset group ($P < 0.05$), and there was a significant difference between the means. $There was a significant difference as a result of the analysis of variance, but in the Scheffe's homogeneous subgroup, it appeared as a single group. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

patients but without significance and also smaller in hypodivergent patients than in hyperdivergent and normovergent patients. However, there have been few studies directed at the relationship of the ILG to skeletal patterns. Therefore, more studies should be considered.

In the present study, mento-labial sulcus depth (MLSD) had a negative but insignificant correlation with the ILG. This might be due to the frequency of lip redundancy, and the consequent deepening of the mentolabial sulcus in the small ILG group.[6] Bishara et al.[30,31] suggested that retruded lips and a small lip thickness (LT) caused a reduced ILG. In the present study, an increased upper lip to E-line (UL-EL) and lower lip to E-line (LL-EL) distances were related to a large ILG but an increased LT was not associated with high ILG.

Burstone[7] believed that UIE during rest or smiling would provide a valuable reference for orthodontic tooth movement. It was demonstrated that UIE and the ILG should be considered together with lower-face vertical dimension. In the present study, the ILG increased as UIE increased which indicated that UIE had a significant effect on the ILG. Burstone[7] suggested that a relaxed lip position was reproducible, but it was difficult for a posed smile to be reproduced. There can be a large variation in smiles, even in the same patient. Therefore, a smile cannot be used as an accurate guide for tooth positioning and treatment planning.[4,7] Similarly, in the present study, the smile line was not correlated with the ILG and FWS.

Previous studies[32–35] have evaluated the characteristics of the posed smile which were classified based on UIE and upper lip position into three categories: "low smile" (less than 75% of UIE), "average smile" (75–100% of UIE and the exposure of the interproximal gingiva), and "high smile" (exposure of a band of contiguous maxillary gingiva). Peck et al.[34] concluded that factors including anterior vertical maxillary excess, greater muscular ability to raise the upper lip upon smiling, excessive overjet and overbite, and excessive ILG at RP were related to a high smile, and ULL, MPA, and PPA were not associated with the gingival smile line. In the present study, the smile line was not related to the amount of ILG and FWS. The distribution of patients was evaluated using different smile lines according to the ILG and FWS, and it was determined that the average smile line was more prevalent than other smile lines in keeping with the findings of previous studies.[32,33]

Table V. Cephalometric measurements at rest position (RP) according to the amount of interlabial gap (ILG) and freeway space (FWS) at RP.

	Means (SD, mm) and *P* values								
	Total (n=104)	ILG<3 (n=40)	3≤ILG≤4 (n=31)	ILG>4 (n=33)	*P* value	FWS<1.2 (n=36)	1.2≤FWS≤2 (n=31)	FWS>2 (n=37)	*P* value
Skeletal variables									
Sum	397.04 (6.36)	396.88 (6.38)	396.11 (6.10)	398.10 (6.61)	0.454	397.75 (6.28)	396.11(5.71)	397.13 (7.00)	0.574
MPA	28.65 (5.67)	28.62 (5.25)	27.48 (4.94)	29.78 (6.68)	0.273	29.06 (6.05)	27.80 (4.95)	28.96 (5.94)	0.611
AFH	131.33 (10.65)	131.83 (11.82)	128.02 (9.52)	133.84 (9.63)	0.085 (0.088)	131.50 (11.26)	131.74 (10.59)	130.82 (10.37)	0.934
PFH	84.32 (12.36)	83.61 (15.72)	83.60 (10.34)	85.87 (9.29)	0.689 (0.730)	82.29 (14.99)	86.58 (11.04)	84.41 (10.41)	0.368 (0.755)
FHR (PFH/AFH)	64.63 (4.95)	64.63 (5.12)	65.16 (4.78)	64.12 (4.98)	0.708	64.05 (4.66)	65.56 (4.91)	64.41 (5.26)	0.439 (0.599)
ANB	3.31 (2.61)	2.58 (2.68)	3.49 (2.34)	4.03 (2.60)	0.055 (0.100)	3.22 (2.39)	3.54 (2.21)	3.21 (3.12)	0.845
AO-BO	−3.10 (4.05)	−3.80 (4.75)	−3.15 (3.41)	−2.21 (3.58)	0.247 (0.255)	−3.40 (3.35)	−2.11 (3.49)	−3.63 (4.95)	0.262 (0.306)
Dental variables									
OJ	3.52 (2.68)	2.91 (2.77)	3.64 (2.65)	4.13 (2.51)	0.143	3.07 (2.44)	3.89 (2.11)	3.64 (3.27)	0.437 (.282)
OB	0.19 (2.57)	0.09 (2.66)	0.11 (2.54)	0.37 (2.55)	0.881 (0.881)	1.22^{b} (2.07)	0.68^{b} (1.62)	−1.24^{a} (3.03)	<0.001*** (0.001**)
IIA	123.03 (10.81)	124.08^{b} (8.40)	127.27^{b} (12.49)	117.76^{a} (9.84)	0.001**	121.04^{a} (9.47)	119.37^{a} (9.14)	128.03^{b} (11.69)	0.001**
OPA	12.92 (4.50)	12.16 (4.08)	13.17 (4.35)	13.60 (5.09)	0.374	13.01 (3.86)	11.62 (4.99)	13.91 (4.50)	0.111
FWS	1.87 (1.24)	1.58 (1.15)	2.18 (1.43)	1.94 (1.09)	0.119 (0.097)	0.79 (0.33)^{a}	1.60^{b} (0.21)	3.16^{c} (1.13)	<0.001*** (<0.001***)
Soft tissue variables									
NLA	93.25 (10.37)	92.92 (10.79)	92.92 (10.75)	93.96 (9.76)	0.894 (0.921)	95.48 (9.03)	92.27 (12.91)	91.90 (9.07)	0.279 (0.217)
UL-EL	2.03 (3.03)	0.64^{a} (2.96)	2.27^{a,b} (2.66)	3.49^{b} (2.74)	<0.001*** (<0.001***)	1.90 (3.26)	1.97 (2.71)	2.20 (3.12)	0.907 (0.669)
LL-EL	3.72 (3.05)	2.64^{a} (2.56)	3.17^{a} (2.64)	5.55^{b} (3.18)	<0.001*** (<0.001***)	4.09 (3.24)	3.84 (2.57)	3.27 (3.24)	0.506 (0.912)
ULL	27.87 (3.10)	28.16^{a,b} (3.13)	26.63^{a} (3.04)	28.69^{b} (2.82)	0.021*	28.35 (3.06)	27.90 (3.50)	27.39 (2.77)	0.418
LLL	48.11 (5.36)	48.86 (5.78)	47.23 (5.51)	48.02 (4.68)	0.447	47.44 (5.27)	48.23 (4.71)	48.86 (6.00)	0.620
LLR (LLL/ULL)	2.02 (0.20)	2.01 (0.22)	2.05 (0.21)	2.01 (0.18)	0.662	1.97 (0.20)	2.03 (0.21)	2.06 (0.20)	0.124
MLA	143.99 (12.34)	145.95 (13.66)	141.06 (10.54)	144.35 (12.04)	0.249	143.53 (13.07)	146.44 (12.17)	142.37 (11.74)	0.387
MLSD	4.17 (1.55)	3.86 (1.57)	4.55 (1.52)	4.19 (1.51)	0.183	4.22 (1.68)	3.85 (1.42)	4.39 (1.51)	0.353
ULT	14.92 (2.47)	14.59 (2.05)	15.33 (2.87)	14.94 (2.53)	0.462	14.16^{a} (2.34)	14.46^{a} (2.23)	16.05^{b} (2.42)	0.002**
LLT	18.10 (14.50)	16.31 (1.70)	21.49 (26.37)	17.096 (2.15)	0.294 (0.329)	16.33 (1.81)	21.31 (26.41)	17.13 (1.91)	0.332 (0.185)
STCT	13.74 (2.38)	13.54 (2.18)	14.08 (2.43)	13.66 (2.59)	0.485	13.40 (2.17)	13.81 (2.00)	14.01 (2.85)	0.536
Z-angle	73.12 (8.43)	74.16 (5.56)	72.76 (12.98)	72.21 (5.57)	0.596 (0.204)	73.47 (4.94)	73.71 (5.72)	72.31 (12.30)	0.761 (0.612)
UIE	2.60 (1.89)	1.94^{a} (1.62)	2.36^{a} (1.48)	3.61^{b} (2.15)	<0.001*** (0.001**)	2.66 (1.88)	2.76 (1.86)	2.10 (1.95)	0.711 (0.623)
ILG	3.58(1.74)	2.02^{a} (0.65)	3.46^{b} (0.26)	5.54^{c} (1.46)	<0.001*** (0.001**)	3.24 (1.80)	3.38 (1.35)	4.04 (1.90)	0.111 (0.088)

FHR, facial height ratio, PFH/AFH (%); LLR, lip length ratio, LLR/ULR (%); UIE, upper incisor exposure. The Shapiro–Wilk normality test was performed and the nonparametric test results are presented in parentheses when normality was not satisfied. The letter a<b indicated differently was analysed by Scheffe's homogeneous subset group ($P < 0.05$), and there was a significant difference between the means. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table VI. Cephalometric changes from maximum intercuspal position (MIP) to rest position (RP) according to the amount of interlabial gap (ILG) and freeway space (FWS) at RP.

	Means (SD, mm) and *P* values								
	Total (*n*=104)	ILG<3 (*n*=40)	3≤ILG≤4 (*n*=31)	ILG>4 (*n*=33)	*P* value	FWS<1.2 (*n*=36)	1.2≤FWS≤2 (*n*=31)	FWS>2 (*n*=37)	*P* value
Skeletal variables									
Sum	1.30 (1.68)	1.15 (1.54)	1.66 (1.92)	1.15 (1.59)	0.365 (0.476)	0.64^{b} (1.16)	0.87^{b} (1.23)	2.30^{a} (1.97)	<0.001*** (<0.001***)
MPA	1.26 (1.74)	1.04 (1.55)	1.62 (2.00)	1.19 (1.70)	0.362 (0.440)	0.52^{b} (1.14)	0.97^{b} (1.27)	2.22^{a} (2.13)	<0.001*** (<0.001***)
AFH	2.24 (2.17)	1.81 (1.80)	2.90 (2.74)	2.16 (1.86)	0.105 (0.129)	1.14^{b} (1.69)	1.89^{b} (1.03)	3.61^{a} (2.56)	<0.001*** (<0.001***)
PFH	0.23 (6.64)	−1.00 (10.54)	1.15 (1.50)	0.85 (1.27)	0.326 (0.451)	−1.36 (11.05)	1.06 (1.29)	1.07 (1.53)	0.210 (0.160)
FHR (PFH/AFH)	−0.49 (1.26)	−0.46 (1.10)	−0.59 (1.52)	−0.45 (1.20)	0.882 (0.978)	$-0.26^{a,b}$ (0.93)	-0.18^{a} (1.05)	-0.98^{b} (1.55)	0.012* (0.034*)
ANB	0.29 (0.90)	0.26 (0.77)	0.51 (0.96)	0.12 (0.98)	0.226	-0.06^{b} (0.60)	0.09^{b} (0.72)	0.80^{a} (1.06)	<0.001*** (<0.001***)
AO-BO	−0.35 (1.60)	−0.30 (1.22)	−0.13 (1.69)	−0.62 (1.91)	0.455 (0.781)	−0.64 (1.15)	−0.25 (1.17)	−0.15 (2.19)	0.404 (0.302)
Dental variables									
OJ	−0.05 (1.62)	0.32 (1.42)	−0.17 (1.51)	−0.39 (1.88)	0.154 (0.145)	-0.50^{b} (1.29)	-0.33^{b} (1.08)	0.62^{a} (2.04)	0.005** (0.012*)
OB	−1.92 (1.93)	−1.50 (1.65)	−2.46 (2.23)	−1.92 (1.89)	0.114 (0.078)	-0.67^{a} (1.06)	-1.51^{a} (1.10)	-3.47^{b} (2.10)	<0.001*** (<0.001***)
IIA	−0.55 (1.58)	−0.39 (1.54)	−0.80 (1.74)	−0.51 (1.49)	0.552	−0.24 (1.31)	−0.49 (1.59)	−0.91 (1.78)	0.197
OPA	0.61 (1.47)	0.50 (1.33)	0.63 (1.60)	0.73 (1.55)	0.800	0.27^{b} (1.25)	0.14^{b} (1.24)	1.34^{a} (1.60)	0.001** (0.002**)
Soft tissue variables									
NLA	−2.08 (4.52)	-0.81^{a} (3.70)	-1.37^{a} (3.91)	-4.29^{b} (5.23)	0.002** (0.001**)	−2.24 (4.07)	−2.38 (3.81)	−1.68 (5.48)	0.792
UL-EL	0.73 (1.02)	0.72 (1.08)	0.64 (0.96)	0.84 (1.04)	0.730 (0.821)	0.49^{b} (0.88)	$0.59^{a,b}$ (1.07)	1.09^{a} (1.04)	0.028* (0.033*)
LL-EL	1.01 (1.59)	0.51^{b} (2.06)	$1.11^{a,b}$ (.88)	1.52^{a} (1.29)	0.022* (0.052)	0.87 (1.06)	1.10 (1.12)	1.08 (2.26)	0.796 (0.254)
ULL	−0.16 (0.96)	0.16^{b} (0.81)	-0.02^{b} (0.76)	-0.69^{a} (1.10)	<0.001***	−0.35 (1.06)	−0.20 (0.61)	0.06 (1.08)	0.179
LLL	−0.45 (1.62)	0.03^{b} (1.34)	0.28^{b} (1.42)	-1.72^{a} (1.38)	<0.001***	−0.85 (1.43)	−0.25 (1.60)	−0.23 (1.78)	0.191
LLR (LLL/ULL)	−0.01 (0.10)	−0.02 (0.10)	0.02 (0.08)	−0.03 (0.11)	0.210	−0.00 (0.09)	−0.00 (0.09)	−0.02 (0.12)	0.721
MLA	−4.54 (5.80)	−3.93 (6.26)	−3.89 (4.75)	−5.90 (6.05)	0.267	−4.18 (6.27)	−3.11 (4.84)	−6.10 (5.84)	0.094
MLSD	0.46 (0.72)	0.30 (0.67)	0.44 (0.52)	0.69 (0.87)	0.064	0.47 (0.76)	0.28 (0.59)	0.61 (0.75)	0.178
ULT	0.65 (1.34)	0.49 (1.50)	0.44 (1.00)	1.04 (1.36)	0.122	0.72 (1.25)	0.74 (1.11)	0.50 (1.59)	0.692
LLT	2.20 (14.56)	0.61 (1.50)	5.46 (26.59)	1.07 (1.43)	0.330 (0.513)	0.74 (1.27)	5.73 (26.54)	0.66 (1.69)	0.276 (0.808)
STCT	−0.40 (4.71)	−0.03 (0.73)	−1.32 (8.27)	0.02 (2.32)	0.434	0.12 (0.86)	−1.14 (8.33)	−0.29 (2.04)	0.550
Z-angle	−0.74 (6.74)	−0.11 (1.33)	2.26 (12.21)	0.08 (1.14)	0.331 (0.833)	−0.36 (1.21)	−0.20 (1.02)	2.60 (11.06)	0.113 (0.055)

FHR, facial height ratio, PFH/AFH (%); LLR, lip length ratio, LLR/ULR (%). The Shapiro–Wilk normality test was performed and the nonparametric test results are presented in parentheses when normality was not satisfied. The letter a < b indicated differently was analysed by Scheffe's homogeneous subset group ($P < 0.05$), and there was a significant difference between the means. $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

Table VII. Frequency distributions of lip competence and incompetence, and smile line according to the amount of interlabial gap (ILG) and freeway space (FWS) at rest position (RP).

	Interlabial gap (ILG)				Freeway space (FWS)			
Total (n=104)	Small ILG<3 mm (n = 40) n (%)	Medium 3 mm≤ILG≤4 mm (n = 31) n (%)	Large ILG>4 mm (n = 33) n (%)	P value	Small FWS<1.2 mm (n =36) n (%)	Medium 1.2 mm≤FWS≤2 mm (n = 31)	Large FWS>2 mm (n = 37) n (%)	P value
	n (%)	n (%)	n (%)		n (%)	n (%)	n (%)	
Lip competence	27 (40.3%)	25 (37.3%)	15 (22.4%)	0.157	25 (37.3%)	19 (28.4%)	23 (34.3%)	0.658
(n = 67)	(67.5%)	(80.6%)	(45.5%)		(69.4%)	(61.3%)	(62.2%)	
Lip incompetence	13 (35.1%)	6 (16.2%)	18 (48.6)	0.053	11 (29.7%)	12 (32.4%)	14 (37.8%)	0.828
(n = 37)	(32.5%)	(19.4%)	(54.5%)		(30.6%)	(38.7)	(37.8%)	
P value	0.027*	0.001**	0.602		0.020*	0.209	0.139	
Low smile line	8 (28.6%)	10 (35.7%)	10 (35.7%)	0.867	11 (39.3%)	7 (25.0%)	10 (35.7%)	0.629
(n = 28)	(20.0)	(32.3%)	(30.3%)		(30.6%)	(22.6%)	(27.0%)	
Average smile line	29 (46.0%)	17 (27.0%)	17 (27.0%)	0.102	20 (31.7%)	19 (30.2%)	24 (38.1%)	0.717
(n = 63)	(72.5%)	(54.8%)	(51.5%)		(55.6%)	(61.3%)	(64.9%)	
High smile line	3 (23.1%)	4 (30.8%)	6 (46.2%)	0.584	5 (38.5%)	5 (38.5%)	3 (23.1%)	0.735
(n = 13)	(7.5%)	(12.9%)	(18.2%)		(13.9%)	(16.1%)	(8.1%)	
P value	<0.001***	0.017*	0.060		0.009**	0.004**	<0.001***	

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

It has been hypothesised that the cephalometric correlations between the ILG and FWS, and several variables could have clinical implications. However, the present study has the common limitation of a small sample size. Due to the ethics of exposing patients to unnecessary radiation doses, the number of patients was, of necessity, kept as low as possible. However, it may be of greater benefit to the patient if a better diagnosis is determined. Patient co-operation in achieving RP was another limitation, especially for children. Patients with an airway problem were excluded, but airway problems are able to affect ILG and FWS, so a future study should be considered to evaluate the changes of ILG and FWS in association with disordered breathing. The present study was prospective but static and so it would be beneficial to investigate the various functional perioral soft tissue movements to enhance orthodontic diagnosis and treatment. Therefore, a future study is recommended to assess the dynamic functional state by applying a similar three-dimensional comparison of pre- and post-treatment outcomes to help clarify the various modality treatment effects on the ILG and FWS.

Conclusions

Cephalometric measurements at MIP and RP were evaluated and compared.

1. The ILG ($P > 0.05$) and FWS ($P < 0.01$) was greater in males than in females.
2. The ILG ($P < 0.05$) and FWS ($P > 0.05$) was greater in adolescents than in adults.
3. The ILG was smaller and FWS was greater in hypodivergent patients than in hyperdivergent and normovergent patients ($P > 0.05$).
4. The ILG was the greatest in Class II subjects but without significance. FWS was significantly greater in Class III than in Class I and Class II subjects ($P < 0.05$).
5. At MIP, the ILG at RP increased significantly as overjet and upper lip to esthetic line increased.
6. At RP, the ILG increased significantly as UIE and lips to EL increased, and FWS decreased significantly as overbite decreased.
7. From MIP to RP, lip length showed the greatest decrease in the large ILG group ($P < 0.001$). Additionally, Bjork sum, MPA, AFH, and ANB angle showed the greatest increase ($P < 0.001$), while OB showed the greatest decrease in the large FWS group ($P < 0.001$).
8. The lip competent group was proportionally greater in the small ILG and FWS groups.
9. The frequency distribution of the smile line showed no relationship with the amount of the ILG and FWS.

The null hypothesis was rejected but there were some differences identified between the groups. Knowing the cephalometric measurements at RP would be helpful to more accurately evaluate the ILG and FWS and to achieve a more precise diagnosis and a predictable treatment plan.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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